OFFICE OF FOSSIL ENERGY

The Office of Fossil Energy responsibilities include management of the Department's fossil fuels (coal, oil and natural gas) research and development program. This research is generally directed by the Office of Coal Technology (OCT), the Office of Gas and Petroleum Technology, and the Office of Advanced Research and Special Technologies in support of the National Energy Strategy Goals for Increasing Energy Efficiency, Securing Future Energy Supplies, Respecting the Environment, and Fortifying our Foundations. Three specific fossil energy goals are currently being pursued:

- The first is to secure liquids supply and substitution. This goal targets the enhanced production of domestic petroleum and natural gas, the development of advanced, cost-competitive alternative fuels technology, and the development of coal-based, end-use technology to substitute for oil in applications traditionally fueled by liquid and gaseous fuel forms.

- The second is to develop power generation options with environmentally superior, high-efficiency technologies for the utility, industrial, and commercial sectors. This goal targets the development of super-clean, high-efficiency power generation technologies.

- The third is to pursue a global technology strategy to support the increased competitiveness of the U.S. in fossil fuel technologies, to maintain world leadership in our fossil fuel technology base, and provide expanded markets for U.S. fuels and technology. This crosscutting goal is supported by the activities in the above two technology goals.

OFFICE OF ADVANCED RESEARCH

FOSSIL ENERGY AR&TD MATERIALS PROGRAM

Fossil Energy (FE) materials-related research is conducted under an Advanced Research and Technology Development (AR&TD) Materials subactivity and is an integral part of the R&D conducted by the Office of Advanced Research and Special Technologies. The AR&TD Materials program includes cross-cutting research to obtain a fundamental understanding of materials and how they perform in fossil-based process environments and the development of new classes of generic materials that will allow the development of new fossil energy systems or major improvements in existing systems. The present program is focused on ceramics (composite structural ceramics, catalyst supports, solid state electrolytes, membranes, and ceramic filters), new alloys (aluminides, advanced austenitic steels, and coatings and claddings), corrosion research, and technology development and transfer.

The AR&TD research is carried through development and technology transfer to industry. Special emphasis is being given to technology transfer to ensure that the materials will be available for subsequent fossil commercial applications. This also enhances U.S. technological competitiveness not only in the fossil area but in the materials industry in general and other technology application areas as well. The research is conducted in industry, universities, not-for-profit agencies, and national laboratories. This widespread participation also helps maintain the U.S. materials technology capabilities.

MATERIALS PREPARATION, SYNTHESIS, DEPOSITION, GROWTH OR FORMING

425. **COATING PROCESS DEVELOPMENT FOR Cr-Nb ALLOYS**
$90,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Ohio State University Contact: R. A. Rapp, (614) 292-6178

Cr-Nb alloys are being developed for high temperature service, but require protection from high temperature environments, such as oxidation. Previously developed $MoSi_2$-base coatings have shown some promise for protecting Nb, and the principles learned may have applicability for protective coatings of Cr-Nb. The purpose of this work is to examine the protection of Cr-Nb alloys with either silicides or aluminides.

Keywords: Alloys, Aluminizing, Chromizing, Corrosion, Coatings

426. **PROCUREMENT OF ADVANCED AUSTENITIC AND ALUMINIDE ALLOYS**
$50,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824

This task provides funds for the procurement of alloys necessary for alloy development and testing activities of the AR&TD Materials Program.

Keywords: Alloys, Aluminides, Austenitic

427. **DEVELOPMENT OF IRON ALUMINIDES**
$170,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: C. G. McKamey, (423) 574-6917

The objective of this task is to develop low-cost and low-density intermetallic alloys based on Fe_3Al with an optimum combination of strength, ductility, weldability, and corrosion resistance for use as components in advanced fossil energy conversion systems. Emphasis is on the development of iron aluminides for heat recovery applications in coal gasification systems.

Keywords: Alloys, Aluminides, Intermetallic Compounds

428. **ULTRAHIGH TEMPERATURE INTERMETALLIC ALLOYS**
$200,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: C. T. Liu, (423) 574-4459

The objective of this task is to develop high-strength, corrosion-resistant intermetallic alloys for use as hot components in advanced fossil energy conversion and power generation systems. The successful development of these alloys is expected to improve the thermal efficiency of fossil energy conversion systems through increased operating temperatures and to increase the service life of hot components exposed to corrosive environments at elevated temperatures (1000°C). The work is focused on *in situ* composite alloys based on the Cr-Cr_2Nb system.

Keywords: Alloys, Chromium-Niobium, Corrosion, Intermetallic Compounds

429. **MICROALLOYED IRON ALUMINIDES**
$78,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: C. G. McKamey, (423) 574-6917

The objective of this task is to use microalloying techniques to further develop the Fe_3Al-based alloys. Emphasis is on producing a low-cost, low-density, precipitation-strengthened Fe_3Al-based intermetallic alloy with improved high-temperature creep resistance while maintaining an optimum combination of room-temperature and high-temperature (600-700°C) tensile properties, weldability, and corrosion resistance for use as structural components of advanced fossil energy conversion systems.

Keywords: Alloys, Aluminides, Microalloy

430. **LOW-ALUMINUM CONTENT IRON-ALUMINUM ALLOYS**
$75,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: V. K. Sikka, (423) 574-5112

The objective of this task is to develop a conventionally fabricable low-cost and lower density iron-aluminum-based alloy with a good combination of strength, ductility, weldability, and corrosion resistance for use as components in advanced fossil energy systems. Initial emphasis is on the development of iron-aluminum alloys for heat-recovery applications in coal gasification systems.

Keywords: Alloys, Iron-Aluminum

431. **Mo-Si ALLOY DEVELOPMENT**
$10,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: C. T. Liu, (423) 574-4559

The objective of this task is to develop new-generation corrosion-resistant Mo-Si alloys for use as hot components in advanced fossil energy conversion and power generation systems. The successful development of Mo-Si alloys is expected to improve the thermal efficiency and performance of fossil energy systems through increased operating temperature and to increase the service life of

hot components exposed to corrosive environments at high temperatures (to 1600°C). The initial effort is devoted to Mo_5Si_3-base alloys containing boron additions.

Keywords: Alloys, Molybdenum, Silicon

432. **TECHNOLOGY TRANSFER - IRON ALUMINIDES**
$60,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: V. K. Sikka, (423) 574-5112

A Cooperative Research and Development Agreement (CRADA) has been established with ABB Combustion Engineering for the development of corrosion-resistant surface protection for fossil power systems.

Keywords: Alloys, Iron-Aluminum, Corrosion, Technology Transfer

433. **COMMERCIAL-SCALE MELTING AND PROCESSING OF LOW-ALUMINUM CONTENT ALLOYS**
$50,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: V. K. Sikka, (423) 574-5112

The purpose of this activity is the preparation and evaluation of castings of FAPY alloy. The castings will be prepared in several types of molds including: (1) graphite, (2) sand, and (3) investment. Castings will be prepared primarily from the air-induction-melted material. Selected graphite and investment castings will also be prepared from the vacuum- induction-melted material. The graphite and sand castings will be prepared at ORNL and will also be procured from the commercial foundries. The castings will be evaluated for porosity, grain structure, mechanical properties, and weldability. The mechanical property evaluation will consist of Charpy, tensile, and creep testing.

Keywords: Alloys, Iron-Aluminum, Melting, Casting

434. **DEVELOPMENT OF A MODIFIED 310 STAINLESS STEEL**
$120,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: R. W. Swindeman, (423) 574-5108

The purpose of this task is to evaluate structural alloys for improved performance of high-temperature components in advanced combined-cycle and coal-combustion systems.

Keywords: Materials, Mechanical Properties, Austenitics, Hot-Gas

435. **TECHNOLOGY TRANSFER - ADVANCED AUSTENITICS**
$80,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: R. W. Swindeman, (423) 574-5108

A Cooperative Research and Development Agreement (CRADA) has been established with ABB Combustion Engineering for the development of advanced austenitic alloys for fossil power systems.

Keywords: Alloys, Austenitics, Technology Transfer

436. **INFLUENCE OF PROCESSING ON MICROSTRUCTURE AND PROPERTIES OF ALUMINIDES**
$175,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Idaho National Engineering Laboratory Contact: R. N. Wright, (208) 526-6127

The purpose of this project is to determine the influence of processing on the properties of alloys based on Fe_3Al. Thermomechanical processing is pursued to improve their room-temperature ductility. The response of the microstructure to annealing will be characterized in terms of the establishment of equilibrium phases and degrees of long-range order. The mechanical properties are determined at room and elevated temperatures and related to the microstructure.

Keywords: Aluminides, Processing, Microstructure

437. **INVESTIGATION OF ELECTROSPARK DEPOSITED COATINGS FOR PROTECTION OF MATERIALS IN SULFIDIZING ATMOSPHERES**
$75,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Pacific Northwest National Laboratory Contact: R. N. Johnson, (509) 375-6906

The purpose of this task is to examine the use of the electrospark deposition coating process for the application of corrosion-, erosion-, and wear-resistant coatings to candidate heat exchanger (including superheater and reheater) alloys. Materials to be deposited may include MCrAl, MCrAlY, highly wear-resistant carbides, and other hardsurfacing materials.

Keywords: Coatings, Materials, Deposition

438. **TECHNOLOGY TRANSFER - ELECTROSPARK DEPOSITED COATINGS FOR PROTECTION OF MATERIALS IN SULFIDIZING ATMOSPHERES**
$80,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Pacific Northwest National Laboratory Contact: R. N. Johnson, (509) 375-6906

The purpose of this task is to transfer to industry the electrospark deposition coating process technology for the application of corrosion-, erosion-, and wear-resistant coatings to candidate heat exchanger [including superheater and reheater] alloys.

Keywords: Coatings, Materials, Deposition

439. **ENGINEERING-SCALE DEVELOPMENT OF THE VAPOR-LIQUID-SOLID (VLS) PROCESS FOR THE PRODUCTION OF SILICON CARBIDE FIBRILS**
$0 (PYF)*
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
The Carborundum Company Contact: S. K. Lau, (716) 278-2004

The purpose of this work is to transfer to industry a specific technology developed by the DOE AR&TD Materials Program for the production of silicon carbide fibrils for the reinforcement of ceramic matrices. The Vapor-Liquid-Solid (VLS) process was developed at Los Alamos National Laboratory for the growth of silicon carbide fibrils of up to 75 mm in length which can be reduced in length by subsequent processing. The purpose of the work is to develop the VLS process into an engineering-scale process that will enable the U.S. industrial sector to commercialize the process for the production of fibrils for the reinforcement of structural ceramic components.

Keywords: Whiskers, Fibers, Ceramic

440. **CERAMIC COMPOSITE PROCESSING EQUIPMENT**
$30,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: D. P. Stinton, (423) 574-4556

This task provides funds for the procurement of major equipment items necessary for AR&TD Materials Program activities.

Keywords: Equipment

*PYF denotes that funding for this activity, active in FY 1995, was provided from prior year funds.

441. **FABRICATION OF FIBER-REINFORCED COMPOSITES BY CHEMICAL VAPOR INFILTRATION AND DEPOSITION**
$150,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: D. P. Stinton, (423) 574-4556

The purpose of this task is to develop a process for the fabrication of fiber-reinforced ceramic composites having high fracture toughness and high strength. This process utilizes a steep temperature gradient and a pressure gradient to infiltrate low-density fibrous structures with gases, which deposit solid phases to form the matrix of the composite. Further development of this process is needed to fabricate larger components of more complex geometry, and to optimize infiltration for shortest processing time, greatest density and maximum strength.

Keywords: Composites, Fiber-Reinforced, Ceramics

442. **COMPLIANT OXIDE COATING DEVELOPMENT**
$75,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: D. P. Stinton, (423) 574-4556

Monolithic SiC heat exchangers and fiber-reinforced SiC-matrix composite heat exchangers and filters are susceptible to corrosion by alkali metals at elevated temperatures. Protective coatings are currently being developed to isolate the SiC materials from the corrodents. Unfortunately, these coatings typically crack and spall when applied to SiC substrates. The purpose of this task is to determine the feasibility of using a compliant material between the protective coating and the substrate. The low-modulus compliant layer could absorb stresses and eliminate cracking and spalling of the protective coatings.

Keywords: Ceramics, Oxides, Coatings

443. **DEVELOPMENT OF OXIDATION/CORROSION-RESISTANT COMPOSITE MATERIALS AND INTERFACES**
$127,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: D. P. Stinton, (423) 574-4556

Fiber-reinforced SiC-matrix composites have been observed to fail in fossil energy applications for two reasons. First, the mechanical properties of composites deteriorate under stressed oxidation because oxidants such as steam penetrate cracks formed in the SiC matrix and react with the carbon or boron nitride interface. The mechanical properties of composites may degrade because of corrosion due to sodium species typically present in fossil systems. Therefore, the purposes of this task are to first, develop fiber-matrix interfaces that are resistant to oxidation and yet optimize the mechanical behavior of composites, and second, to develop protective overcoats or oxide matrices that are resistant to oxidation and corrosion.

Keywords: Composites, Ceramics, Fiber-Reinforced, Interfaces

444. **OPTIMIZATION OF THE CHEMICAL VAPOR INFILTRATION TECHNIQUE FOR CERAMIC COMPOSITES**
$85,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
University of Tennessee Contact: Peter Liaw, (423) 974-6356

This project is focused on an optimization of the forced chemical vapor infiltration technique for fabrication of ceramic matrix composites (CMCs) using process models. In particular, a process model developed at the Georgia Tech Research Institute shall be thoroughly investigated. Experimental verification of the process model shall be conducted in light of microstructural characterization using both destructive and nondestructive evaluation techniques. An optimized process for manufacturing CMCs shall be demonstrated. Moreover, mechanistic understanding regarding the effects of processing parameters on microstructural features, and fatigue and fracture behavior of CMCs shall be provided.

Keywords: Composites, Fiber-Reinforced, Ceramics

445. **TRANSPORT PROPERTIES OF CERAMIC COMPOSITES**
$148,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Georgia Institute of Technology Contact: T. L. Starr, (404) 853-0579

The purpose of this research effort is to conduct a theoretical and experimental program to identify new compositions and processing methods to improve the

physical and mechanical properties of selected fiber-reinforced ceramics. The ceramic matrix material is amorphous fused silica or modified silica glass, and the focus is the development of fiber-reinforced silica. Parameters studied include: (1) differences in elastic modulus between matrix and fiber, (2) differences in thermal expansion, (3) nature of interfacial bond, (4) densification of matrix, (5) nature of fiber fracture/pull-out, (6) fiber diameter and fiber length-to-diameter ratio, (7) fiber loading, and (8) fiber dispersion and orientation. A model will be developed based on the information generated in the experimental phase of the program.

Keywords: Ceramics, Composites, Fiber-Reinforced

446. **MODELING OF FIBROUS PREFORMS FOR CVD INFILTRATION**
$50,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Georgia Institute of Technology Contact: T. L. Starr, (404) 853-0579

The purpose of this project is to conduct a theoretical and experimental program to develop an analytical model for the fabrication and infiltration of fibrous preforms. The analytical model will: (1) predict preform structure (density, porosity, fiber orientation, etc.) based on fabrication technique and fundamental fiber parameters (diameter, aspect ratio, etc.), and (2) predict permeation and heat conduction through the preform structure and, thus, predict the CVD infiltration performance.

Keywords: Ceramics, Composites, Modeling

447. **CORROSION PROTECTION OF SiC-BASED CERAMICS WITH CVD MULLITE COATINGS**
$50,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Boston University Contact: Vinod Sarin, (617) 353-6451

This project involves the growth of dense mullite coatings on SiC-based substrates by chemical vapor deposition. SiC and SiC-based composites have been identified as the leading candidate materials for stringent elevated temperature applications. At moderate temperatures and pressures, the formation of a thin self-healing layer of SiO_2 is effective in preventing catastrophic oxidation by minimizing the diffusion of O_2 to the substrate. The presence of impurities can increase the rate of passive oxidation by modifying the transport rate of oxygen through the protective scale, can cause active oxidation via formation of SiO which accelerates the degradation process, or can produce compositions such as Na_2SO_3 which chemically attack the ceramic via rapid corrosion. There is therefore a critical need to develop adherent oxidation/corrosion-resistant, and thermal-shock-resistant coatings that can withstand such harsh environments. Mullite has been identified as an excellent candidate material due to its desirable properties of toughness, corrosion resistance, and a good coefficient of thermal expansion match with SiC.

Keywords: Ceramics, Coatings

448. **FEASIBILITY OF SYNTHESIZING OXIDE FILMS ON CERAMIC AND METAL SUBSTRATES**
$100,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Lawrence Berkeley Laboratory Contact: Ian Brown, (510) 486-4174

The objective of this project is the study of the feasibility of synthesizing metal oxide ceramic films on ceramic and metal substrates. This feasibility will be demonstrated by use of plasma-based deposition and ion mixing techniques. The films shall be characterized for properties such as composition, structure, hardness, high temperature oxidation resistance, adhesion to the substrate, and stability to high temperature cycling. The value of intermediate transition or buffer layers, composed of materials with suitably matched thermal expansion characteristics and atomically graded interfaces, as a technique for improving the high temperature survivability of the films, shall be explored. Samples shall be formed on substrates of various shapes and sizes, including perhaps on the inside and outside of pipes, as well as on small flat coupons. The issue of deposition onto and atomic mixing into substrates which are insulating shall be addressed experimentally. The work is divided into two parts: (1) Al_2O_3 films on alumina-forming alloy substrates, and (2) oxides on SiC.

Keywords: Ceramics, Films, Oxides

449. **SCREENING ANALYSIS OF CERAMIC HOT-GAS FILTER MATERIALS**
$0 (PYF)*
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Pennsylvania State University Contact: R. E. Tressler, (814) 865-7961

This project will include a screening analysis of candidate ceramic hot-gas filter materials. A flow-through screening test will be developed to test ceramic hot-gas filter elements in simulated coal combustion environments.

Keywords: Ceramics, Corrosion, Coatings

450. **ENVIRONMENTAL EFFECTS ON CERAMICS**
$100,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contacts: P. F. Tortorelli, (423) 574-5119

The purpose of this work is to support the development of advanced ceramics and ceramic composites for applications in fossil environments by examining critical issues related to high-temperature corrosion resistance. More specifically, the overall objective of this task is to examine the chemical compatibility and reliability of potentially corrosion-resistant ceramics being developed as protective overcoats and/or structural materials as parts of other work elements funded by the AR&TD Program.

Keywords: Coatings, Corrosion

451. **CERAMIC COATING EVALUATION**
$100,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contacts: P. F. Tortorelli, (423) 574-5119

The purpose of this work is to generate the information needed for the development of improved (slow growing, adherent, sound) protective oxide coatings and scales. The specific objectives are to (1) systematically investigate the relationships among substrate composition and surface oxide structure, adherence, soundness, and micromechanical properties, (2) use such information to predict scale and coating failures, and (3) identify and evaluate compositions and synthesis routes for producing materials with damage-tolerant scales and coatings.

Keywords: Coatings, Corrosion

452. **METAL DUSTING STUDY**
$25,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contacts: P. F. Tortorelli, (423) 574-5119

The objective of this task is to establish the potential risk of operating problems due to carbon deposition and metal dusting in advanced coal gasification processes and to identify methods for avoiding carbon deposition. The work involves a literature search, compilation of a bibliography of relevant articles, and a summary of the current state of knowledge.

Keywords: Coatings, Corrosion

453. **LOW-TEMPERATURE FABRICATION OF TRANSPARENT SILICON NITRIDE**
$100,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
National Institute of Standards and Technology Contact: S. G. Malghan, (301) 975-6101

The objective of this research is the production of dense, hard, transparent ceramics from nanosize particles without the use of sintering aids. The work will concentrate on the fabrication of samples of transparent silicon nitride using the cryogenic compaction technique. TEM, SEM, X-ray diffraction, and laser light scattering will be used to characterize the microstructure. Hardness at various temperatures will be measured to assess the creep resistance of the material. Fracture toughness and bending strength will also be measured.

Keywords: Ceramics, Mechanical Properties

*PYF denotes that funding for this activity, active in FY 1995, was provided from prior year funds.

454. **MICROWAVE-ASSISTED CHEMICAL VAPOR INFILTRATION**
$25,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: M. A. Janney, (423) 574-4281

The purpose of this research effort is to explore the feasibility of using microwave heating to enhance the chemical vapor infiltration (CVI) process developed under the Fossil Energy Materials Program (FEMP) sponsorship. The goal is to achieve faster deposition rates, greater control over deposition conditions and resulting microstructures, and perhaps lower temperature infiltration.

Keywords: Ceramics, Microwave Processing

455. **DEVELOPMENT OF MICROWAVE-HEATED DIESEL PARTICULATE FILTERS**
$75,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: M. A. Janney, (423) 574-4281

The purpose of this research, which derives from our work on ceramic filters for coal systems, is to help develop microwave-heated diesel engine particulate filter/burner devices. The goal is to develop materials that will perform both as filter and heater in such a device. A Cooperative Research and Development Agreement (CRADA) between Lockheed Martin Energy Systems and the Cummins Engine Company is in place that supports this work, CRADA No. ORNL93-0172. We propose to develop a ceramic composite structure of SiC-coated ceramic fiber that can be used as a diesel engine particulate filter. For commercial usage a particulate filter must: (1) filter carbon particles from high temperature diesel exhaust gas at an acceptable (low) backpressure; (2) survive thousands of thermal transients caused by regeneration (cleaning) of the filter by oxidizing the collected carbon; (3) be durable and reliable over the life of the filter, which is in excess of 300,000 miles (10,000 hours of operation); and (4) provide a low overall operating cost which is competitive with other filtering techniques.

Keywords: Ceramics, Microwave Processing

456. **CARBON FIBER COMPOSITE MOLECULAR SIEVES**
$275,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: T. D. Burchell, (423) 576-8595

Hydrogen recovery technologies are required to allow the upgrading of heavy hydrocarbons to transport fuels, thus reducing the amount of carbon rejected during the conversion of fossil resources into hydrocarbon products. The purpose of this work is to develop carbon molecular sieves (CMS) starting with porous carbon fiber composites (CFC) manufactured from petroleum pitch derived carbon fibers. The carbon fiber composite molecular sieves (CFCMS) will be utilized in pressure swing adsorption units for the efficient recovery of hydrogen from synthesis gas, refinery purge gases, and for other gas separation operations associated with hydrogen recovery.

Keywords: Carbon Fibers, Sieves, Composites

457. **CARBON MATERIALS EQUIPMENT**
$15,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: T. D. Burchell, (423) 576-8595

This task provides funds for the procurement of major equipment items necessary for AR&TD Materials Program activities.

Keywords: Equipment

458. **ACTIVATION OF CARBON FIBER COMPOSITE MOLECULAR SIEVES**
$75,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
University of Kentucky Contact: Frank Derbyshire, (606) 257-0305

A novel monolithic adsorbent carbon, manufactured from carbon fibers, has been invented jointly by researchers at Oak Ridge National Laboratory (ORNL) and the University of Kentucky Center for Applied Energy Research. The novel material, referred to as a carbon-fiber composite molecular sieve (CFCMS) is fabricated at ORNL in the Carbon Materials Technology Group. The purpose of this activity is to activate samples of the CFCMS and to perform subsequent analyses of the surface area, pore width distributions, and micropore volume. Activities are directed toward an

485. **SUPPORT SERVICES FOR CERAMIC FIBER-CERAMIC MATRIX COMPOSITES**
$25,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
University of North Dakota Energy and Environmental Research Center Contact: J. P. Hurley, (701) 777-5159

This task will review and, if appropriate, propose modifications to plans, materials, and tests planned by researchers on the AR&TD Materials Program in work to test materials for coal-fueled energy systems. The changes shall be suggested in order to make the corrosion experiments more reflective of the actual conditions that will be encountered by the materials in the energy systems. UNDEERC shall accomplish this task by reviewing the major advanced energy system projects being funded by the DOE, and by working with the company's technical monitor and staff to prepare a summary of the expected corrosion problems. Both gasification and combustion systems will be included. Ceramic materials in two subsystems will be the focus of this work: (1) hot gas cleanup systems and (2) high-temperature heat exchangers. UNDEERC shall review and suggest improvements to materials testing procedures that are used to determine material behavior when used in hot-gas cleanup or heat exchanger applications. A limited amount of computer modeling and laboratory experimentation shall be a part of this effort.

Keywords: Composites, Ceramics, Fibers

486. **DEVELOPMENT OF NONDESTRUCTIVE EVALUATION METHODS AND EFFECTS OF FLAWS ON THE FRACTURE BEHAVIOR OF STRUCTURAL CERAMICS**
$310,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Argonne National Laboratory Contacts: W. A. Ellingson, (708) 252-5068 and J. P. Singh, (708) 252-5123

The purpose of this project is to study and develop acoustic and radiographic techniques and possible novel techniques such as nuclear magnetic resonance, to characterize structural ceramics with regard to presence of porosity, cracking, inclusions, amount of free silicon, and mechanical properties, and to establish the type and character of flaws that can be found by nondestructive evaluation (NDE) techniques. Both fired and unfired specimens are being studied to establish correlations between NDE results and failure of specimens.

Keywords: Nondestructive Evaluation, Ceramics, Flaws, Fracture

487. **FRACTURE BEHAVIOR OF ADVANCED CERAMIC HOT-GAS FILTERS**
$125,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
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Keywords: Ceramics, Flaws, Fracture, Failure

488. **CERAMIC CATALYST MATERIALS**
$225,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Sandia National Laboratories Contact: A. G. Sault, (505) 844-8723

The purpose of this research is to investigate the role of ceramic material properties in the catalytic activity of a novel class of catalytic supports, known as hydrous titanium oxides (HTO). Catalysts prepared on these materials show particular promise as economically and environmentally attractive alternatives to present commercial catalysts for the direct liquefaction of coal. In these studies, improved understanding and control of the synthesis process is being pursued in order to tailor the composition, molecular structure, microporosity, and physical/mechanical properties of the HTO thin films. The effects of altered structure, composition, and other material

463. **CONVERSION OF PITCHES AND COKES FROM SOLVENT-EXTRACTED MATERIALS**
$0 (PYF)*
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Koppers Industries, Inc. Contact: R. McHenry, (412) 826-3989

The closure of by-product coke ovens has caused the domestic production of coal tar pitch to decline at 3 percent to 4 percent per annum during the mid-1990s. This reduction has directly affected Koppers' capability to produce required quantities of quality binder and impregnating pitches used in the aluminum and commercial carbon and graphite industries. Moreover, the other major constituent of carbon anodes and graphites is a coke, usually produced from petroleum pitch precursors, 50 percent of which are imported. The objectives of this research are to develop dependable domestic coal-based raw materials for the production of: binder pitches for aluminum cell anodes and commercial carbon and graphite products; impregnating pitches for commercial carbon and graphite products and specialty materials; oils for wood treatment and carbon black production; chemicals for phthalic anhydride and other products; and metallurgical and foundry grade cokes.

Keywords: Coke, Pitch, Conversion

464. **CARBON FIBER COMPOSITE MOLECULAR SIEVES**
$155,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: T. D. Burchell, (423) 576-8595

Hydrogen and Methane gas recovery technologies are required to: (1) allow the upgrading of heavy hydrocarbons to transport fuels, thus reducing the amount of carbon rejected during crude oil refining and (2) to improve the yield and process economics of natural gas wells. The purpose of this work is to develop carbon fiber composite molecular sieves (CFCMS) from porous carbon fiber composites manufactured from solvent extracted coal tar pitch derived carbon fibers. The work will be performed in collaboration with other members of the Cooperative Research Partnership on Carbon Products and the Non Fuel Uses of Coal.

Keywords: Consortium, Carbon Products

465. **DEVELOPMENT OF PRECURSORS FOR PRODUCTION OF GRAPHITES AND CARBON PRODUCTS**
$0 (PYF)*
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
UCAR Carbon Company Contact: Irv Lewis, (216) 676-2203

The manufacture of graphite utilizes cokes and pitches derived from petroleum refining by-products and by-product coke ovens. These include isotropic and anisotropic cokes, binder, and impregnant pitches. Assuring feedstock quality is of great importance to the graphite industry. Therefore, a stable long-lived source of feedstock pitch (and hence coke) would be of considerable benefit to the industry. Consequently, UCAR Carbon Company Inc. shall work with staff members at the Oak Ridge National Laboratory and at the West Virginia University to develop suitable precursor pitches, binders, impregnants, and cokes for the production of graphites and other carbon products.

Keywords: Carbon Products, Precursors, Graphites

466. **PRODUCTION OF YARN FROM VLS WHISKERS**
$100,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824

In order to exploit the superior thermomechanical properties of fibrils produced by the Vapor-Liquid-Solid (VLS) Process, the feasibility of scaled-up production of the SiC fibril will be demonstrated in this activity. Through time-series study and computer simulation, the parameters affecting the growth process and properties of the fibrils will be examined.

Keywords: Whiskers, Fibers, Ceramic

*PYF denotes that funding for this activity, active in FY 1995, was provided from prior year funds.

485. **SUPPORT SERVICES FOR CERAMIC FIBER-CERAMIC MATRIX COMPOSITES**
$25,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
University of North Dakota Energy and Environmental Research Center Contact: J. P. Hurley, (701) 777-5159

This task will review and, if appropriate, propose modifications to plans, materials, and tests planned by researchers on the AR&TD Materials Program in work to test materials for coal-fueled energy systems. The changes shall be suggested in order to make the corrosion experiments more reflective of the actual conditions that will be encountered by the materials in the energy systems. UNDEERC shall accomplish this task by reviewing the major advanced energy system projects being funded by the DOE, and by working with the company's technical monitor and staff to prepare a summary of the expected corrosion problems. Both gasification and combustion systems will be included. Ceramic materials in two subsystems will be the focus of this work: (1) hot gas cleanup systems and (2) high-temperature heat exchangers. UNDEERC shall review and suggest improvements to materials testing procedures that are used to determine material behavior when used in hot-gas cleanup or heat exchanger applications. A limited amount of computer modeling and laboratory experimentation shall be a part of this effort.

Keywords: Composites, Ceramics, Fibers

486. **DEVELOPMENT OF NONDESTRUCTIVE EVALUATION METHODS AND EFFECTS OF FLAWS ON THE FRACTURE BEHAVIOR OF STRUCTURAL CERAMICS**
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Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Argonne National Laboratory Contacts: W. A. Ellingson, (708) 252-5068 and J. P. Singh, (708) 252-5123

The purpose of this project is to study and develop acoustic and radiographic techniques and possible novel techniques such as nuclear magnetic resonance, to characterize structural ceramics with regard to presence of porosity, cracking, inclusions, amount of free silicon, and mechanical properties, and to establish the type and character of flaws that can be found by nondestructive evaluation (NDE) techniques. Both fired and unfired specimens are being studied to establish correlations between NDE results and failure of specimens.

Keywords: Nondestructive Evaluation, Ceramics, Flaws, Fracture

487. **FRACTURE BEHAVIOR OF ADVANCED CERAMIC HOT-GAS FILTERS**
$125,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
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Keywords: Ceramics, Flaws, Fracture, Failure

488. **CERAMIC CATALYST MATERIALS**
$225,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Sandia National Laboratories Contact: A. G. Sault, (505) 844-8723

The purpose of this research is to investigate the role of ceramic material properties in the catalytic activity of a novel class of catalytic supports, known as hydrous titanium oxides (HTO). Catalysts prepared on these materials show particular promise as economically and environmentally attractive alternatives to present commercial catalysts for the direct liquefaction of coal. In these studies, improved understanding and control of the synthesis process is being pursued in order to tailor the composition, molecular structure, microporosity, and physical/mechanical properties of the HTO thin films. The effects of altered structure, composition, and other material

472. **FIRESIDE CORROSION TESTS OF CANDIDATE ADVANCED AUSTENITIC ALLOYS, COATINGS, AND CLADDINGS**
$80,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Foster Wheeler Development Corporation Contact: J. L. Blough, (201) 535-2355

The purpose of this project is to provide comprehensive corrosion data for selected advanced austenitic tube alloys in simulated coal ash environments. ORNL-modified alloys and standard comparison alloys have been examined. The variables affecting coal ash corrosion and the mechanisms governing oxide breakdown and corrosion penetration are being evaluated. Corrosion rates of the test alloys are determined as functions of temperature, ash composition, gas composition, and time.

Keywords: Austenitics, Alloys, Corrosion

473. **JOINING TECHNIQUES FOR ADVANCED AUSTENITIC ALLOYS**
$50,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
University of Tennessee Contact: C. D. Lundin, (423) 974-5310

Weldability is an important consideration in the selection of a suitable alloy for the fabrication of boiler components such as superheaters and reheaters. It is often a challenge to select joining materials and establish procedures that will allow advanced materials to function at their full potential. The purpose of this research is to examine important aspects of newly developed austenitic tubing alloys intended for service in the temperature range 550 to 700°C.

Keywords: Alloys, Austenitics, Joining, Welding

474. **FATIGUE AND FRACTURE BEHAVIOR OF Cr-Nb ALLOYS**
$20,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
University of Tennessee Contact: Peter Liaw, (423) 974-6356

The objective of this research shall be to characterize the fatigue and fracture behavior of Cr_2Nb-based alloys and other intermetallic materials at ambient and elevated temperatures in controlled environments. These studies are expected to lead to mechanistic understanding of the fatigue and fracture behavior of these alloys. Fatigue tests shall be conducted for the purpose of evaluating crack initiation and fatigue life of Cr_2Nb-based alloys as well as other intermetallic alloys. The fatigue properties shall be evaluated as functions of test environment, cyclic frequency and test temperature. Additional tensile tests will be required to characterize the fracture behavior of these structural alloys. Mechanical tests shall be performed to determine the fatigue and fracture behavior of Cr_2Nb-based alloys. The microstructure of the alloys shall be characterized and correlated with the mechanical properties.
Keywords: Fracture, Fatigue, Alloys

475. **CORROSION AND MECHANICAL PROPERTIES OF ALLOYS IN FBC AND MIXED-GAS ENVIRONMENTS**
$310,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Argonne National Laboratory Contact: K. Natesan, (708) 252-5103

The purposes of this task are to: (1) evaluate the corrosion mechanisms for chromia- and alumina-forming alloys in mixed-gas environments, (2) develop an understanding of the role of several microalloy constituents in the oxidation/sulfidation process, (3) evaluate transport kinetics in oxide scales as functions of temperature and time, (4) characterize surface scales that are resistant to sulfidation attack, and (5) evaluate the role of deposits in corrosion processes.

Keywords: Corrosion, Gasification, Creep Rupture, Fluidized-Bed Combustion

485. **SUPPORT SERVICES FOR CERAMIC FIBER-CERAMIC MATRIX COMPOSITES**
$25,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
University of North Dakota Energy and Environmental Research Center Contact: J. P. Hurley, (701) 777-5159

This task will review and, if appropriate, propose modifications to plans, materials, and tests planned by researchers on the AR&TD Materials Program in work to test materials for coal-fueled energy systems. The changes shall be suggested in order to make the corrosion experiments more reflective of the actual conditions that will be encountered by the materials in the energy systems. UNDEERC shall accomplish this task by reviewing the major advanced energy system projects being funded by the DOE, and by working with the company's technical monitor and staff to prepare a summary of the expected corrosion problems. Both gasification and combustion systems will be included. Ceramic materials in two subsystems will be the focus of this work: (1) hot gas cleanup systems and (2) high-temperature heat exchangers. UNDEERC shall review and suggest improvements to materials testing procedures that are used to determine material behavior when used in hot-gas cleanup or heat exchanger applications. A limited amount of computer modeling and laboratory experimentation shall be a part of this effort.

Keywords: Composites, Ceramics, Fibers

486. **DEVELOPMENT OF NONDESTRUCTIVE EVALUATION METHODS AND EFFECTS OF FLAWS ON THE FRACTURE BEHAVIOR OF STRUCTURAL CERAMICS**
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Argonne National Laboratory Contacts: W. A. Ellingson, (708) 252-5068 and J. P. Singh, (708) 252-5123

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Keywords: Nondestructive Evaluation, Ceramics, Flaws, Fracture

487. **FRACTURE BEHAVIOR OF ADVANCED CERAMIC HOT-GAS FILTERS**
$125,000
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Keywords: Ceramics, Flaws, Fracture, Failure

488. **CERAMIC CATALYST MATERIALS**
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Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Sandia National Laboratories Contact: A. G. Sault, (505) 844-8723

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480. **OXIDE DISPERSION STRENGTHENED (ODS) IRON ALUMINIDE EQUIPMENT**
$35,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: I. G. Wright, (423) 574-4451

This task provides funds for the procurement of major equipment items necessary for AR&TD Materials Program activities.

Keywords: Equipment

481. **OXIDE DISPERSION STRENGTHENED (ODS) IRON ALUMINIDES**
$222,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: I. G. Wright, (423) 574-4451

The purpose of this task is to develop fabrication procedures for making oxide dispersion-strengthened (ODS) iron-aluminum alloys based on Fe_3Al. The suitability of the procedures is measured in terms of the high-temperature oxidation and sulfidation resistance and creep strength of the ODS alloys compared with Fe_3Al alloys fabricated by conventional ingot and powder processes.

Keywords: Aluminides

482. **MATERIALS SUPPORT FOR HITAF**
$0 (PYF)*
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: K. Breder, (423) 574-5089

This task involves the measurement of selected mechanical and physical properties of structural ceramics which are proposed for use in the construction of the High Temperature Advanced Furnace (HITAF) air heater design being developed under the Combustion 2000 program for PETC/DOE. The purpose of the research is to evaluate candidate structural ceramics for this application by studying the fast fracture and fatigue (both dynamic and interrupted static) properties at temperatures from 1100 to 1400°C in air, their corrosion behavior, property uniformity of components and long term degradation of ceramic properties due to exposure in prototype HITAF systems.

This work is continuing with funding from the Combustion 2000 Program.

Keywords: Furnace, Materials, HITAF

483. **CHARACTERIZATION OF LOW-EXPANSION CERAMIC MATERIALS AND DEVELOPMENT OF SOL GEL-DERIVED COATINGS AS INTERFACES FOR SIC COMPOSITES**
$23,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
University of Tennessee Contact: Peter Liaw, (423) 974-6356

The purpose of this activity is the experimental study of low-expansion ceramic materials and the development of sol-gel derived coatings as interfaces for Nicalon®/SiC composites

Keywords: Composites, Ceramics

484. **JOINING OF CERAMICS**
$50,000
DOE Contacts: J. P. Carr, (301) 903-6519 and E. E. Hoffman, (423) 576-0735
Oak Ridge National Laboratory Contact: N. C. Cole, (423) 574-4824
Idaho National Engineering Laboratory Contact: B. H. Rabin, (208) 526-0058

The purpose of this project is to explore and develop joining techniques for silicon carbide fiber-reinforced silicon carbide ceramics produced by chemical vapor infiltration and deposition (CVID). The research goals include identifying appropriate joining methods, establishing experimental procedures for fabricating joints, and characterizing the structure and properties of joined materials. An understanding of the factors that control joint performance is sought through studies of the relationships among processing variables, joint microstructures, and mechanical properties. Additional funds for this project are provided by the DOE Pittsburgh Energy Technology Center.

Keywords: Ceramics, Joining, Technology Transfer

*PYF denotes that funding for this activity, active in FY 1995, was provided from prior year funds.

485. **SUPPORT SERVICES FOR CERAMIC FIBER-CERAMIC MATRIX COMPOSITES**
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